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# Report of the Committee on CELLULOID STORAGE

*Presented by the Secretary of State for the Home Department to Parliament  
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# REPORT OF THE CELLULOID STORAGE COMMITTEE

To the RT. HON. JAMES CHUTER EDE, M.P., *Secretary of State for the Home Department.*

SIR,

1. In accordance with our appointment in June, 1948, we have considered the report of Mr. A. J. Long, K.C., into the circumstances of a fire at the premises of Alfred Harris and Co., Ltd., Richmond,\* and we have enquired into, and now have the honour to submit our report upon the suitability of, or the need for amendment of, the regulations under the Factories Acts and the Celluloid and Cinematograph Film Act, 1922, which govern the storage of celluloid. We have also taken into consideration the three local Acts dealing with the storage of celluloid, viz., the London County Council (Celluloid, etc.) Act, 1915, the Liverpool Corporation Act, 1921, and the Glasgow Streets Sewers and Buildings Consolidation Order Confirmation Act, 1937.

You announced the circumstances of our appointment in reply to Questions put to you in the House of Commons by Mr. R. Sargood, M.P., on 8th July, 1948, and by Brigadier Sir Harvie Watt, M.P., on 25th November, 1948.

## INTRODUCTION

2. For the purpose of our enquiry we have visited eight premises in the Home Counties to acquaint ourselves with conditions under which celluloid is stored. With the assistance of the Factory Department and of the local authorities an investigation was made for us in nine areas (selected by our members as districts in which a wide range of activities involving the storage of celluloid or of cinematograph film might be found), so that we might, by sampling, obtain a picture of the general standard of storage conditions. We also invited twenty-two witnesses to discuss various practical storage questions with us in the light of their own personal views and experience. The Ministry of Supply and the Air Ministry have supplied information on the disposal of surplus stocks of R.A.F. photographic film, and the Ministry of Health on the storage of X-ray film in hospitals. We have analysed all available reports since 1942 on fires, excluding cinema fires, in which celluloid or cinematograph film was involved. Dr. Kingman of the Joint Fire Research Organisation and Mr. R. C. Bevan of the Building Research Station have assisted on the technical side of our study. Mr. Lister, H.M. Engineering Inspector of Factories, and Mr. Martin of the Cardiff Fire Service deputised for their principals on occasions. We are greatly indebted to all who have helped us in these various ways. The premises visited by the Committee, the areas investigated and the representatives of trade organisations who were consulted are listed in Appendix I. We have met thirty-one times.

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\* Enquiry into the fire at the premises of Alfred Harris & Co., Ltd., at Townshend Terrace, Richmond, Surrey, on 4th September, 1947 (Cmd. 7440).



3. Mr. Long's report was based on a public enquiry into a fire at a factory in Richmond, the origin of which could not be discovered. The fire was of an alarming and rapid character and caused the deaths of six people living in houses in close proximity to the factory and considerable damage to two factory premises and to residential and other property in the immediate vicinity. So far as celluloid was present on the premises Mr. Long found (paragraph 3) that there was "storage pending resale of scrap celluloid cinematograph film, celluloid film punchings, small cylinders and celluloid scrap". None of this material was sorted or graded or subjected to any process at the factory. Mr. Long suggested that any proposals for amendments to existing legislation on the subject of celluloid storage "should have regard not merely to activities of the kind carried on in Harris's factory and to the circumstances of the fire there, but should also have regard to the other activities involved in the various trades in which the storage of celluloid in its different forms is involved and to the knowledge acquired from the circumstances of other fires where large quantities of celluloid have burned" (paragraph 35).

4. In 1913 and again in 1938 Departmental Committees\* reported upon the uses of celluloid and upon the safety measures required to minimise danger from the inflammable character of the material. The 1938 report contains detailed information about the variety of uses of celluloid (Section 4 and Appendix IV) but does not concern itself with storage as such. The report of 1913 contains a number of recommendations related to storage in retail shops, wholesale shops and warehouses, raw celluloid stores, factories (including those in which raw celluloid is made and those in which there is use of celluloid in manufacturing processes and in solutions) and the report deals also with the storage of cinematograph film. It is noteworthy that the storage of scrap celluloid is not dealt with in the report of 1913 as a separate trade activity, although, as stated above, it was storage of this character which was involved in the Richmond fire.

## THE PROBLEM AND ITS SCOPE

5. *The term celluloid* covers substances which have in common the feature that all contain nitrated cellulose,† which is highly inflammable and decomposes at moderate temperatures, giving off gases which are poisonous and form explosive mixtures with air. Scientific research has not confirmed that celluloid is liable to spontaneous ignition.‡ Existing statutory provisions, in so far as they define it, base the definition of "celluloid" on the presence in a substance of nitrated cellulose, or other nitrated products,§ and the

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\* Report of the Departmental Committee on Celluloid, 1913 (Cmd. 7158), and Report of the Departmental Committee on the Use of Celluloid in the Manufacture of Toys, Fancy Goods, etc., 1938 (Cmd. 5790).

† See the nature of Celluloid and Celluloid Substitutes in Section 1 of Report of the Departmental Committee on the Use of Celluloid in the Manufacture of Toys, Fancy Goods, etc., 1938.

‡ In this connection we have had regard to the report on "The Surveillance of Cinematograph Record Film during Storage" produced by the Government Chemist's Department and the Chemical Research and Development Establishment of the Ministry of Supply, (February, 1948), and the Report of the Departmental Committee on Celluloid, 1913, neither of which offers any evidence of spontaneous ignition under tests conducive to such action.

§ See Celluloid and Cinematograph Film Act, 1922 (Section 9), and Regulations of 1921 for Factories and Workshops where celluloid, etc., is manufactured (S.R. & O. 1921 No. 1825).

presence of these substances forms part of the statutory definitions of cinematograph film.\* It should be observed that photographic films and old stocks of X-ray films may also be composed of celluloid.

6. In view of the greater ease of ignition of certain forms of celluloid, which was accepted by our witnesses, it is necessary in relation to storage precautions to have regard to the kind of celluloid to be stored. For reasons given later we do not consider that the existing statutory control, which we discuss in the next section of our report, takes sufficient account of differences in the kind of celluloid to be stored, e.g., raw celluloid is defined in the Act of 1922 as meaning both “(a) celluloid which has not been subjected to any process of manufacture, and (b) celluloid scrap or waste”. We consider that the ease of ignition of celluloid scrap or waste (which was the kind of celluloid involved in the Richmond fire) is so great that the storage precautions for scrap or waste require separate consideration from those for raw celluloid as defined in (a) below. Again, there are detailed storage requirements for cinematograph film, whereas photographic film which is of comparable fire risk is only subject to statutory control when stored in factory premises and even then to less stringent requirements. We have therefore classified the celluloid storage position in terms of four main classes as follows:—

(a) *Raw celluloid*, including celluloid in the form of sheets, blocks, tubes or rods which form the basis for many manufactured articles. Where these sheets, etc., approximate in thickness to cinematograph or photographic film, it seems to us to be essential that the conditions of storage should not be those for the thicker sheets which do not ignite so readily but should be those which we propose should in future govern the storage of such film (see (c) below). An expert trade witness proposed a thickness of  $5\frac{1}{2}/1,000$ th inch, with other qualifications, as the limit below which celluloid should be treated as film, but we prefer to state the thickness in general terms.

(b) *Manufactured articles* containing celluloid, in factories, warehouses and shops. Our sample investigation showed that in districts covered by the enquiry there was little storage of manufactured celluloid articles, other than film, in quantities of more than one cwt. in shops or warehouses and this, it is thought, may be considered to be typical of the country as a whole. One of the reasons given for the shortage of manufactured celluloid articles in shops was that the extensive pre-war imports from Germany and Japan have ceased. Moreover, in the manufacture of a number of small articles celluloid has been superseded by slow-burning plastic substances. In the circumstances we find no reason to dissent from the view expressed in paragraph 19 of the Report of the Departmental Committee of 1913, that there is no need for regulations dealing specifically with the storage of manufactured celluloid goods in shops nor for requirements for storage in warehouses.

(c) *Cinematograph and photographic (including X-ray) film*. This material represents great fire danger especially when it is “stripped”. This category should embrace any film (including uncoated raw base) containing nitro-cellulose or other nitrated product, which was made for the purpose of being used in cinematograph or photographic apparatus of any type (e.g., cameras, sound recording apparatus, and projectors or X-ray apparatus). We consider also that certain thin sheet celluloid should be included in this category (see (a) above).

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\* See also The Manufacture of Cinematograph Film Regulations, 1928 (S.R. & ●. 1928, No. 82) and The Cinematograph Stripping Regulations, 1939 (S.R. & ●. 1939, No. 571).



(d) *Scrap or waste celluloid*, which consists of the scrap or waste products of (a) to (c) above, and would include stripped (or washed) film. In bulk, this presents a potential fire danger greater even than that presented by film, because of the greater ease of ignition of the small pieces of which scrap often consists and of its miscellaneous character. The risk is often increased by certain unsatisfactory ways in which scrap or waste is packed for storage and for transport.

Where the term "celluloid", without qualification, is used in this report it is intended to include all the above four classes, unless the context clearly indicates the contrary.

7. *The term "storeroom"* has been taken by us as meaning accommodation (a room, chamber or similar enclosure) used expressly for the storing of any kind of celluloid, including nitro-cellulose film, as distinct from any accommodation in which celluloid or film is subjected to some process or operation. In view of the frequent use of the term "store" or "vault" for a storeroom we should perhaps add that we have regarded each individual store or vault, whether isolated or in vertical or horizontal juxtaposition with others, as a storeroom, in making our recommendations. Activities such as examining, sorting, manipulation, packing and despatch are sometimes carried out in rooms adjacent to storerooms. Although our recommendations are concerned primarily with storerooms as we have defined them, we have also had regard to activities such as examining, sorting, etc., in so far as they are a danger to storage accommodation (see paragraphs 80 to 83). We have not regarded temporary deposit while in the course of or incidental to delivery, conveyance, or transport as constituting storage.

8. *The features of storage*, by which we mean the matters in relation to a celluloid storeroom which are susceptible of regulation, are well known. They are the same features, broadly speaking, as are controlled in respect of many different kinds of other substances which present a danger to persons or property in the vicinity. We have found as regards some features that higher standards are very desirable in place of the existing standards, especially in respect of the storing of the more easily ignitable kinds of celluloid. It may be helpful to list here the features of storage. They are as follows:—

- (i) *Registration or notification* of the existence of a storeroom.
- (ii) *Siting* in relation to (a) the premises associated with the storeroom or (b) neighbouring premises.
- (iii) *Amount* of material to be stored.
- (iv) *Structure*, in which is included not only the materials and construction of the main fabric, walls, doors, ceilings and floors, but also any baffle walls, and fittings of the storeroom.
- (v) *Ventilation and provision for gas relief*.
- (vi) *Lighting heating*.
- (vii) *The means of escape* from the storeroom and other premises in the vicinity.
- (viii) *Means of extinguishing fire*.
- (ix) *Miscellaneous provisions* as to notices in connection with the storeroom, its exclusive use for the storage of celluloid, the prohibition of open lights, smoking materials, etc., and the promotion of "good housekeeping", such as adequate supervision, maintenance, instructions to staff, etc.

9. Some of these features of celluloid storage are inter-related and complementary and whatever care is taken to relate legal requirements to the risk presented by the kind of celluloid to be stored, there are bound to be some unusual or exceptional circumstances which may render a particular requirement unnecessary or inappropriate. It is, therefore, necessary not only to provide for variation of the requirements so as to take account of the form of celluloid to be stored but also to leave room for some discretion to be exercised in the application or enforcement of the requirements.

## EXISTING STATUTORY REGULATIONS

10. The following codes relate to the storage of celluloid and/or cinematograph film:—

A. Under the Factories Acts, there are the following regulations which relate solely to factory premises:—

- (i) The Celluloid Regulations, 1921 (S.R. & O. 1921, No. 1825).
- (ii) The Manufacture of Cinematograph Film Regulations, 1928 (S.R. & O. 1928, No. 82).
- (iii) The Cinematograph Film Stripping Regulations, 1939 (S.R. & O. 1939, No. 571).

B. The Celluloid and Cinematograph Film Act, 1922.

C. Local Acts:—

- (i) The London County Council (Celluloid etc.) Act, 1915.
- (ii) The Liverpool Corporation Act, 1921.
- (iii) The Glasgow Streets Sewers and Buildings Consolidation Order Confirmation Act, 1937.

### A. Regulations under the Factories Acts

(i) *The Celluloid Regulations, 1921*

11. These Regulations apply to all factories or to parts thereof “in which celluloid or any article wholly or partly made of celluloid is manufactured, manipulated or stored”, except that the Regulations of 1928 and 1939 (see paragraphs 14-15 and 16-17) have superseded the Regulations of 1921 in so far as, respectively, the manufacture, repair, manipulation, use or storage of cinematograph film, and the processes of stripping and drying of cinematograph film, are concerned.\* Since these Regulations of 1921 are not confined to those factories in which specific industries are carried on (as are the Regulations of 1928 and 1939) they apply to the great majority of factory premises in which raw celluloid, or manufactured celluloid articles, or scrap or waste celluloid are stored. Of 2,275 registered factories to which one or other of these three codes of factory regulations apply, 2,129 are subject to the provisions of the 1921 Regulations. The 1921 Regulations are designed, therefore, to provide a general code of requirements, including storage requirements, for use in a great variety of industries in which celluloid, in any form, is used.

12. Some of the main features of storage are dealt with generally, but not specifically, in the Regulations of 1921. Ventilation and gas relief are not mentioned and there is no definition of fire resisting material. There is no precise requirement as to siting, except that stocks of celluloid shall be

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\* The definitions of cinematograph film in the Regulations of 1928 and 1939 limit their application to certain types of film. See paragraphs 14 and 16.

kept in a suitable place outside the workrooms plainly marked "Celluloid Store" and that "the store shall not be situated so as to endanger the means of escape from the factory or workshop or from any part thereof in the event of a fire occurring in the store". There are miscellaneous provisions as to prohibiting the admission of unauthorised persons, smoking, naked lights and fires, and a requirement as to the appointment, in writing, of a competent person to supervise and enforce the regulations, and there is provision for H.M. Chief Inspector of Factories to grant conditional exemption to any factory from all or any of the prescribed regulations in any case in which he is satisfied that they are not necessary for the protection of the persons employed.

13. It was these regulations which in Mr. Long's view governed the storage of celluloid and of cinematograph film in Harris's factory, and he commented upon the provisions with regard to amount of material stored, structure of storerooms, and means of extinguishing fire (paragraph 33 of his report) as follows:—

"They require that stocks of celluloid exceeding 1 cwt. shall be kept in a chamber constructed of fire resisting materials, but they contain no provision limiting the amount of celluloid that may be stored in any building provided that the building, or any compartment of the building in which it is stored, answers the description 'a chamber constructed of fire resisting materials'. They require that adequate means for extinguishing fire, having regard to the amount of celluloid present in the room at any one time, shall be kept constantly provided for each storeroom, but unless this provision is to be interpreted as requiring a fire extinguishing apparatus that will operate automatically, it is useless for stopping or controlling an outbreak of fire occurring the factory is closed and no one is present to operate hand appliances."

(ii) *The Manufacture of Cinematograph Film Regulations. 1928*

14. These Regulations apply to all factories or parts thereof "in which cinematograph film is manufactured, repaired, manipulated, used or stored". There are 135 registered factories subject to these provisions. "Cinematograph film" is defined as "any film including uncoated raw base, containing nitro-cellulose or other nitrated product, which is intended for use in a cinematograph or other similar apparatus". Scrap film is covered by these Regulations only in so far as it is the waste from the processes carried out.

15. In the field covered by the Regulations, standards are noticeably more stringent and specific on the main features of storage than those in the Regulations of 1921. The siting of the storeroom is dealt with; structural provisions include a definition of "fire resisting material"; there are requirements as to ventilation and gas relief space, and safeguards are prescribed to prevent the risks of ignition and overheating of film by electrical plant or equipment. On the question of adequate means of extinguishing fire, the 1928 Regulations prescribe that every storeroom shall be fitted with an efficient automatic water sprinkling system, unless it was in use before the 1st March, 1928, and is situated on the roof or top floor of a building or in a single storey building approved by H.M. Chief Inspector of Factories, or some other position similarly approved. Where, however, a storeroom has been brought into use since 1st March, 1928, the above requirements as to siting apply, and in addition an efficient water sprinkling system must be fitted. Finally, there is a provision prescribing the maximum amount of cinematograph film which may be kept in one storeroom, i.e. one



ton or 560 reels whichever is the greater. (In this connection it should be noted that a practice has recently arisen in the trade whereby film is often reeled in 2 100 foot lengths, each weighing about ten pounds ; thus 560 reels may now approximate to 2½ tons.) The regulations contain miscellaneous provisions somewhat similar to those in the Regulations of 1921.

(iii) *The Cinematograph Film Stripping Regulations, 1939*

16. These Regulations apply “to all factories or parts thereof in which stripping\* or drying† of cinematograph film is done”. The definition of “cinematograph film” is “any film containing nitro-cellulose or other nitrated product which was *intended for use or has been used* in a cinematograph or sound recording or other similar apparatus”. There are 11 registered factories subject to these provisions. The Regulations do not therefore apply over a wide field, and do not affect the storage of scrap celluloid (other than cinematograph film) or of scrap photographic film, or of stripped cinematograph film on premises other than a stripping factory.

17. The siting of the storeroom is subject to the approval of H.M. Chief Inspector of Factories who must approve the plans of all premises used for film stripping and, furthermore, any storeroom shall be a single-storey building, and, if erected since 1st December, 1938 “shall be a separate single-storey building at least 20 feet from any building in which persons are regularly present”. The maximum amount of film allowed to be kept in any one storeroom is one ton or other approved quantity. The structural requirements are similar to those imposed by the 1928 Regulations, but there is an additional requirement (the baffle wall) aimed at more effective isolation of one storeroom from another, viz. the storeroom shall be “separated from any adjacent storeroom by a wall built up to 3 feet above the roof”. The basis for calculating the gas relief space results generally in a greater area per storeroom than in the 1928 Regulations and in addition the design must be approved. The provision in the storeroom of a sprinkler system or other means of extinguishing fire is, however, not required. Electrical safeguards are somewhat similar to those in the 1928 Regulations, as are the miscellaneous provisions.

*General observations on the Regulations under the Factories Acts*

18. Before proceeding to deal with the other statutory requirements governing the storage of celluloid, it seems appropriate to consider the general effectiveness of the various factory regulations as a whole in relation to celluloid storage. It is, as we have shown, the Regulations of 1921 which cover by far the greatest number of cases of celluloid storage in factories. In his report Mr. Long found that the prohibitions and precautions imposed by these Regulations (and those in certain relevant paragraphs of the Celluloid and Cinematograph Film Act, 1922, which we discuss in paragraph 25 below) “are inadequate to protect buildings and their occupants from the dangers created by the storage of large quantities of celluloid upon other premises in close proximity to them” (paragraph 36 (h) of his report), but he also pointed out that factory regulations “are intended for the protection of workers in the factory. They are not intended, designed, or adequate for the protection of persons or buildings outside the factory” (paragraph 33). On the other hand, Mr. Long found the standards in the

\* “Stripping” means the removal of emulsion from cinematograph film and includes all unpacking, sorting, unwinding, winding, decolouring, washing, grading, and packing of cinematograph film incidental thereto.

† “Drying” means the drying of cinematograph film from which emulsion has been removed.

Regulations of 1928 and 1939 to be much more satisfactory although they cover only a small and specialised amount of celluloid storage in factories. He goes so far as to say of the Regulations of 1939: "Had these last mentioned requirements been applicable to the storage of the celluloid in Harris's factory and observed there, I think it very probable that the fire would have been confined to a limited portion of the celluloid, or that at any rate its progress would have been considerably retarded and that the damage to neighbouring buildings would have been greatly reduced, if not wholly avoided" (paragraph 38 of his report).

The wider evidence we have now obtained and considered leads us to the conclusion that although that statement may have been justified by the site arrangements of Harris's premises, the requirements of the 1939 Regulations would not necessarily have been sufficient to obviate danger in all cases. In our view a higher standard than that afforded by the 1939 Regulations is justifiable.

19. We find that the existing codes of factory regulations give rise to certain anomalies. For instance, stripped film is stored both by the film stripper who has removed the emulsion from it and by the manufacturer who uses it as raw material in, say, the making of paints, leather cloth, etc. This kind of film has a considerably higher calorific value, and, possibly as the result of the treatment it has received, ignites more freely and burns more fiercely than coated nitro-cellulose film, and it may therefore be regarded as presenting a greater risk. Where stripped film is stored on film strippers' premises it must be stored in accordance with the comprehensive requirements of the Cinematograph Film Stripping Regulations, 1939, but on the paint manufacturer's premises, for example, it need only be stored in accordance with the general and far less stringent provisions of the Celluloid Regulations, 1921, which, in particular, place no limit on the amount which may be kept in one storeroom. It seems most desirable to us that storage conditions be related directly to the risk presented by the kind of celluloid material which is being stored, and that, other things being equal, the use or purposes for which it is being stored is not a material factor.

20. In view of the need for variation, or flexibility, in prescribing storage conditions (which we mention in paragraph 9 above) it is important to note that the regulations under the Factories Acts enable H.M. Chief Inspector of Factories to grant conditional exemption to any factory from all or any of the prescribed regulations, in any case in which he is satisfied that they are unnecessary for the protection of the persons employed.

## **B. The Celluloid and Cinematograph Film Act, 1922**

21. This Act applies

(i) To the keeping or storing, in excess of the minimum quantities prescribed, of raw celluloid, the expression "raw celluloid" being defined as meaning

(a) Celluloid which has not been subjected to any process of manufacture; and

(b) Celluloid scrap or waste.

(ii) To the keeping or storing, in excess of the minimum quantities prescribed, of cinematograph film, which is defined as meaning any film containing celluloid which is intended for use in a cinematograph or any similar apparatus.



The definition of raw celluloid presents certain difficulties in that it might be argued that there can be no celluloid which has not been subjected to *any* process of manufacture. Moreover, as we have indicated in paragraph 6, it is anomalous that sheet celluloid and celluloid scrap should be grouped within the same broad definition and so subject to precisely the same storage requirements. The definition of cinematograph film, which clearly excludes ordinary photographic film, results in the escape of this type of film from the control provided by the Act. Photographic film is controlled when stored in factory premises, and, as it appears to present a danger comparable with that of cinematograph film, we feel that the definition of cinematograph film should be amended to bring photographic film containing nitrated cellulose within the scope of the Act.

22. The Act applies, broadly, to all premises, save those to which the Factories Acts and the Cinematograph Act, 1909, apply, where more than 11 cwt. of raw celluloid or 20 reels or 80 lb. of cinematograph film are stored or kept (including temporary deposit for examination, cleaning, etc.); or where lesser quantities are kept, unless the raw celluloid, or, in the case of cinematograph film, each reel, is kept in a separate and properly closed metal box. The Act does not apply in the administrative County of London or the City and Royal Burgh of Glasgow nor, until it is directed by order that the relevant similar provisions of the Liverpool Corporation Act, 1921, shall cease to apply,\* to the City of Liverpool. Registration with the appropriate local authority is required in respect of any premises to which the Act applies, together with the payment of annual fees.

23. Storage requirements are contained in the First Schedule of the Act. This schedule has many of the weaknesses of the Celluloid Regulations, 1921. As regards structure, there is no definition of what constitutes fire resisting material, and there are no requirements relating to gas relief space or to baffle walls. There is no definition of means of extinguishing fire. The Act requires raw celluloid to be kept in a fire resisting storeroom, but not cinematograph film if it is kept in fire resisting receptacles. Any quantity of the latter may be so kept in one room, and the quantity which may be kept in one receptacle and the positions where such receptacles shall be kept are not specified. On the other hand, the amount of material which may be stored in any one storeroom is limited to one ton of celluloid and one ton or 560 reels (see paragraph 15 above) of cinematograph film. Where both raw celluloid and film are stored, the aggregate amount in one storeroom shall not exceed one ton. There is no limit to the number of storerooms or of receptacles which there may be in one building.

24. The Act of 1922 has regard to the safety of the general public as well as to persons in or about a celluloid storeroom. Paragraphs (c), (d) and (e) of sub-section (1) of Section 1 of the Act, which relate to all premises, including factory premises, in which celluloid or cinematograph film, as defined in the Act, is stored or used, provide that no premises shall be used for any purpose to which the Act applies:—

“(c) If the premises are situated underneath premises used for residential purposes ;

(d) if the premises are so situated that a fire occurring therein might interfere with the means of escape from the building of which they form part or from any adjoining building ;

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\* No order has yet been made.



- (e) where the premises form part of a building, unless such part either
- (i) is separated from any other part of the building by fire resisting partitions (including fire resisting ceilings and floors) and fire resisting self-closing doors ; or
  - (ii) is so situated and constructed that a fire occurring therein is not likely to spread to other parts of the building, and its use for the purposes to which this Act applies is sanctioned in writing by the local authority and any conditions attached to such sanctions are complied with."

#### *General observations on the Act*

25. We think there are weaknesses in these requirements which call for revision. Paragraph (c) is not adequate in that there is evidence of the rapid spread of celluloid fires and we cannot overlook the possibility that fire may spread both laterally and downwards. There is also the question of the spread through the building of the gases evolved on the decomposition of the celluloid. Paragraph (d) was considered in paragraph 32 of Mr. Long's report. He took the view that except for the two storerooms, which were contiguous, there were no "adjoining buildings". Nevertheless the fire at Harris's factory spread to buildings in the vicinity sufficiently quickly to impede the means of escape from them. Mr. Long reported (paragraph 32) with special reference to paragraph (d): "the important matter to note is I think, that these provisions are not framed and are not adequate to protect persons placed in the position of those who suffered fatal injury in Townshend Terrace, namely persons who occupy a neighbouring building which does not actually adjoin the building in which the celluloid is stored, but who may be trapped by the intense conflagration which is likely to ensue if large quantities of the celluloid take fire". The effectiveness of paragraph (e) depends upon how far adequate standards of construction are imposed, or adequate conditions attached by local authorities in cases where they sanction use for storage.

26. We have indicated in paragraph 9 the need for some discretion to be exercisable in the enforcement of statutory requirements relating to celluloid storage. So far as factory premises are concerned H.M. Chief Inspector of Factories already possesses such a power (see paragraph 20), and we recommend that local authorities charged with the enforcement of the Celluloid and Cinematograph Film Act, 1922, should have similar powers. The local authorities in question are at present the county borough councils, borough councils, and urban and rural district councils, and the assignment of duties to them has merit inasmuch as these are the authorities charged with securing adequate means of escape from buildings (under both the Public Health and the Factories Acts). It is significant, however, that other and newer functions which have a bearing on celluloid storage, e.g., those relating to fire protection and town and country planning (although the latter are not specifically based on safety considerations) are exercised by the larger local authorities, viz. the county councils and the county borough councils. If local authorities are given wider and discretionary powers in connection with the storage of celluloid, responsibilities in these other spheres could usefully be co-ordinated with responsibility for celluloid storage, e.g., when considering exemptions the authorities could have regard to other risks in the neighbourhood and to the fire fighting facilities available and could, at all times, take into account changes in the situation. A re-arrangement of this kind need not disturb the present assignment of responsibility for means of escape to the smaller local authorities. In view of these considerations

and such allied factors as the highly technical nature of the control of celluloid storage, and the need for wide experience in securing uniformity of practice in the exercise of discretionary powers, we think that there would be great advantage in placing celluloid storage powers in the hands of the fewer authorities who possess the useful complementary powers we have mentioned. We accordingly recommend that consideration should be given to the question of confining to councils of counties and county boroughs the exercise of the local authorities' powers under the 1922 Act, except for powers relating to means of escape, which might remain with the smaller local authorities.

### C. Local Acts

27. *The London County Council (Celluloid, etc.) Act, 1915*, is typical of the three local Acts dealing with celluloid storage. In one important particular, i.e. the structural provisions relating to storerooms, the Liverpool Corporation Act, 1921, differs from the London Act, but in most of their provisions the three Acts are virtually identical. The three Acts play the same part in their separate districts as the Celluloid and Cinematograph Film Act, 1922, plays in the rest of the country. The London Act of 1915, applies to all premises in the administrative county of London where cinematograph film or such celluloid as has not been subjected to any process of manufacture (in quantities above the minimum quantities prescribed for the operation of the Act of 1922) is stored or otherwise dealt with, provided that it is being kept for the purposes of "sale, hire or profit". One of the deficiencies in the application of this Act is that it does not extend to the storage of celluloid scrap.

28. As regards siting of the storeroom, the London County Council Act contains provisions comparable with paragraph (c) of sub-section (1) of Section 1 of the Act of 1922; it also requires adequate means of escape to be provided from a building used in part for purposes other than a celluloid factory or a celluloid store. The Act does not enable control to be exercised over the position of the storeroom, and many storerooms in London are in fact at basement level. The Council is required to register any premises as a celluloid store within one month of the date of the application for such registration. It cannot refuse to register a store, and cannot cancel a registration except at the request of the person registered. The structural requirements of the Act are a little more precise than those of the Act of 1922, and of the Celluloid Regulations, 1921, in that a standard of fire resisting material is prescribed. The Act also contains a requirement limiting to one ton or 560 reels of film, whichever is the greater, the amount of celluloid which may be kept in one storeroom. In terms of present day reels this may allow storage up to  $2\frac{1}{2}$  tons (see paragraph 15). Requirements with regard to fire extinguishing apparatus, although specific, do not take account of modern appliances, e.g. there is no provision as to sprinklers. There is, however, such a requirement in the Glasgow Act.

29. In view of the considerable concentration of cinematograph film in London, particularly in storerooms in the Wardour Street area (where some of the storerooms are in basements under offices and present a very serious fire and explosion risk to upper floors and to the adjacent buildings as well as to traffic) a strengthening of the London County Council Act is of the first importance.



## ENQUIRIES MADE

30. As stated in paragraph 2 of our report, we made some independent enquiries in various ways for the purpose of acquainting ourselves with celluloid storage practice, bearing in mind the storage conditions at Harris's factory. These enquiries consisted of a sample area investigation, visits to different kinds of storage accommodation in the vicinity of London, an examination of fire reports, and discussion with witnesses from the celluloid industry. We propose to give in this section of our report the salient findings of these enquiries.

### *Sample Area Enquiry*

31. We instituted investigations and received reports from H.M. Inspectors of Factories and local authority officers on celluloid storage in the nine areas listed in Appendix I.

32. We received detailed reports on seventy stores, of which the great majority fell within three categories, viz., factories in which motion pictures are made, factories in which celluloid is used in a manufacturing process, and film renters' premises in which cinematograph film is stored for purposes of distribution. Only two storerooms used by celluloid scrap merchants were found. In two industrial premises, outside London, cinematograph film was stored solely for purposes of exhibition on the premises, and in one of these cases the amount stored was as much as one ton. We understand that this storage and use is subject to the provisions of the Act of 1922.

33. The close proximity of residential, commercial, or industrial property to a number of celluloid storerooms containing anything from 1 ton to 70 tons of celluloid or of film was the disturbing revelation of the reports, having in mind the grave damage which was done to residential property at a distance of as much as 42 feet from the Harris factory. Two instances were reported in London of residential accommodation in the same building as celluloid storerooms. In one case this accommodation was four storeys above the storeroom and, in the other, on the floor below. Again, in one industrial town, a storeroom holding 70 tons of celluloid but having a capacity of 300 tons was situated on the ground floor of a building otherwise used as offices, workrooms and a staff canteen, and at a distance of only 20 feet from the nearest residential property. Cases were also reported where the quantity of film in the basement would imperil, in the event of fire, the means of escape of employees working on the other floors, and also cases where buildings had been allowed to fall into such disrepair that the safety measures originally provided were no longer effective, e.g., fire resisting doors could only be shut with difficulty. On the whole the reports showed compliance with statutory codes, but in one or two cases there were infringements which led to prosecutions.

### *Visits by Committee*

34. We visited eight stores of different kinds in and near London. On the whole the visits confirmed the information on storage obtained from the area enquiry, though in a few cases we found that a higher standard of storage accommodation was provided than is required under the existing law, e.g., sprinklers were fitted in three cases where they were not statutorily necessary. On the other hand we found a case where two storerooms, each containing one ton of film, were situated in the basement of a five-storey building with ventilators from the storerooms leading, at pavement level, to a crowded public street outside. In more than one case storerooms were not being used solely for the storage of celluloid or cinematograph film.



In another instance, a building consisted of a series of adjoining storerooms in different occupations; some were used for the storage of scrap film in sacks and others for the storage of cinematograph film in tins; those used for the former purpose had no sprinklers, although those used for the latter had. In the main store of one factory (to which the Celluloid Regulations, 1921, applied) there were no less than 250-300 tons of sheet celluloid stored in three inter-communicating storerooms. This was not a contravention of the statutory requirements, but we were glad to find additional safeguards adopted voluntarily. Our visits also revealed the importance of having regard to the conditions outside the storerooms. Instances were encountered of corridors so narrow as to be liable to obstruction by the trolleys used to transport film to and from the workrooms, etc.; storerooms with doors directly facing each other; possible sources of fire (e.g., electric signs, chimneys) close to gas relief outlets; gas relief outlets in close proximity to each other; and the use of inflammable solvents in rooms adjacent to storerooms.

### *Fire Reports*

35. We have studied reports on the fires occurring since 1942 in which celluloid and cinematograph film was involved, other than those in cinemas, and in addition to the Richmond fire, to see how far they give us material on safeguarding celluloid storage. There have been twenty-six such fires on which reports were available. Some of these fires occurred during the war period, but, while war conditions may have had some bearing, the fires were not attributable to any war incident. Of these fires, one occurred at a scrap merchant's, three in renters' premises, five in factories, six in studios and eight took place at film strippers' premises. Three fires occurred in places which could not be regarded as normal storage accommodation, e.g., in an open yard. No fire occurred in a sheet celluloid storeroom.

36. In eighteen of these twenty-six fires, storerooms were involved, either originally (thirteen cases) or from a fire elsewhere which spread to the storeroom. Fire spread from the storeroom to other premises in four of the thirteen cases where fire originated in a storeroom, but we do not think we can necessarily infer that in the nine other cases the storerooms were adequate to contain a fire, since in one other instance there would most certainly have been spread of fire to other premises had there been buildings as near as in the Richmond case.

37. In twenty-one cases out of the twenty-six, the material involved was cinematograph film. Of these twenty-one cases, coated cinematograph film was involved on seventeen occasions and stripped film on the other four. The quantities involved were in some cases considerably in excess of the one-ton limit prescribed for storerooms in the existing Regulations. In one fire, at film renters' premises, as much as 50 tons of film were involved. In another case, five tons of scrap (both film and celluloid) caught fire, and eventually involved 70 tons of other inflammable materials, and although the quantities were not similar in kind, the mixture of materials was a point of similarity with the fire at Richmond.

38. Of the thirteen fires which originated in storerooms, there was only one case in which a reason could be found for the outbreak (a hot cinder was inadvertently carried into the storeroom in the turnup of a man's rousers). In seven cases the fire seems to have occurred during a period of hot weather after work had ceased for the day—in most cases some time afterwards. It was suggested in some cases that the fires were due to

spontaneous ignition of film, but there is no scientific evidence to show that this form of ignition occurs (see paragraph 5). In eight cases out of the twenty-six it was reported that the fire was accompanied by an explosion. In one instance, where cinematograph film became ignited in a basement, severe damage was sustained five floors above.

39. In five cases out of the twenty-six, fires occurred in factories which were not concerned with the manufacture or stripping of cinematograph film. In four of the cases the celluloid concerned was, in fact, film. In the other case the fire was extinguished before serious damage had been done.

40. In two cases only out of the twenty-six under review the use of sprinklers was reported. In one case they operated in time to save 300 lbs. of film in a storeroom after only 4 lbs. had burned, and in the other case they saved 60 lbs. of celluloid after only a few sheets had burned.

41. In no case did loss of life occur, nor was severe damage done to property at as great a distance as that recorded at Richmond, but there is a record of scorching of property at a distance of 250 feet, and another case of leaves in an orchard being burned at a distance of 210 feet from the seat of the fire.

#### *Scrap or Waste Celluloid*

42. We addressed our questions to witnesses more particularly on the extent and character of the trade in scrap celluloid and cinematograph film, which was the kind of business carried on at the Harris factory.\* We were told that scrap normally comprised washed (or stripped) and unwashed cinematograph film, film punchings, scrap photographic film, exposed X-ray film (now normally of cellulose-acetate), and waste celluloid articles. We were informed that there were some twenty firms operating as celluloid scrap merchants, some of which were of recent origin, having purchased ex-R.A.F. film, sold in open auctions, and that the firms were either middlemen, who merely collected and resold material as purchased, or were merchants, sorting before resale. We were also told that scrap cinematograph film was stored by film producers prior to disposal, by film strippers, and, after stripping, by firms engaged in the leather cloth, paint and export trades, to which firms 90 per cent. of all scrap film eventually goes. We learned that the import and export trade in scrap film is considerable, involving yearly from two to four hundred tons.

43. We were also informed that it was customary for scrap merchants to receive quantities of mixed plastic material, some of which would be nitro-cellulose and some cellulose-acetate, or other plastic material not regarded as being highly inflammable. It was necessary for the scrap merchant to sort this material, except when it was known that a particular delivery, by virtue of the source of supply, would not contain a heterogeneous assortment of material. It was said that most of this sorting was done amongst the general mass of waste materials on storage premises. Most scrap merchants employed experienced men who could tell by sight or touch the difference between nitro-cellulose and other forms of plastic. It was alleged, however, that there were cases where the test involved placing the material in the flame of a candle, or on an electric hotplate, and determining the nature of the material by the rate of burning. It was also necessary to sort scrap celluloid material from other waste such as cardboard, paper packing, etc., which might amount to as much as 15 per cent. of the contents of the sack (We gathered that it was not unusual for scrap to be stored in sacks, despite

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\* See paragraphs 3 and 21 of Mr. Long's report.



the recommendation of the Departmental Committee of 1913.) The scrap merchant separates the scrap nitro-cellulose according to its thickness, and it was said by more than one witness that the risk of fire in nitro-cellulose of 5/1000th inch or less in thickness is as great as in cinematograph film, irrespective of any difference in the chemical composition of the two materials.

44. As an illustration of the present haphazard growth of "mushroom" middle men or merchants dealing in scrap or waste film, we may mention one case (where a serious fire occurred) where the local authority found that the premises in which photographic film was stored in bulk, and which were not subject to any of the existing codes of requirements, were next door to a day nursery. In another case a vanman detailed to fetch material from a bona fide scrap merchant, was mistakenly directed to a private house where he was given scrap celluloid from the basement.

### STANDARDS RECOMMENDED

45. In considering the standards of storage to be adopted we deal only with those in which modifications are desirable. Otherwise, we desire to see existing standards fully maintained.

#### *Classes of Celluloid*

46. As stated we classify celluloid in four categories: raw celluloid, manufactured celluloid goods, cinematograph and photographic (including X-ray) film and scrap or waste celluloid. As regards raw celluloid (provided it is not defined to include celluloid scrap or waste as in Section 9 of the Act of 1922 and provided that it does not approximate to film), we consider that having regard to its greater difficulty of ignition and lower rate of burning, and the few fires which have taken place in relation to the large number of storerooms involved, there is only need to strengthen the standards of the Regulations of 1921 and the Act of 1922, which are applicable to the storage of raw celluloid, in such a way as to require the provision of sprinklers in storerooms, and to define fire resisting material. While we think it desirable that raw celluloid should be stored in a single storey building or on the roof or top floor of a building, wherever this is reasonably practicable, we feel that, in view of the characteristics of this material to which we referred in the preceding sentence, the specific amendment of Section 1 (1) (d) and (e) of the 1922 Act suggested later (paragraphs 49 and 85 D and E) should be adequate to ensure that storerooms for raw celluloid are sited in safe positions. We consider that the present restriction imposed by the Act of 1922 upon the storage of more than 1 ton of raw celluloid, although essential for celluloid scrap, need not be retained for sheets, blocks, etc., having regard to the new provisions as to siting which we later recommend. We do not, as already stated, consider further regulation of manufactured celluloid articles is necessary. They are already subject to the 1921 Regulations when stored in quantities of more than 1 cwt. in factory premises. As regards cinematograph and similar film and raw celluloid of the same thickness, and as regards scrap or waste celluloid, we propose detailed standards, though, if the storage is so situated, constructed and otherwise circumstanced that it is unnecessary to comply fully with our detailed standards in order to secure the safety of persons or property, a limited measure of discretion should be given to the administering authorities to relax the requirements.



### *Siting of Storerooms*

47. Siting is in many ways the crux of the whole problem. Paragraphs (d) and (e) of Section 1 (1) of the Celluloid and Cinematograph Film Act, 1922 (which apply to factory premises as well as non-factory premises) already regulate the siting of a celluloid storeroom in relation to premises of which the storeroom *forms part* and in relation to any buildings which "*adjoin*" premises used for celluloid storage. As Mr. Long pointed out (see paragraph 25) the provisions of these paragraphs are inadequate to protect buildings and their occupants from the dangers created by the storage of large quantities of celluloid upon other premises in *close proximity* to them. Mr. Long was, however, careful to point out that his criticism was made in the light of the existing statutory provisions relating to the storage of celluloid and that if more stringent requirements had been applicable he thought it "very probable" that the fire at Richmond "would have been confined to a limited portion of the celluloid, or at any rate its progress would have been very considerably retarded, and that the damage to neighbouring buildings would have been greatly reduced, if not wholly avoided". Our enquiries as to the circumstances and consequences of celluloid fires convince us, however, that amendment of Section 1 (1) (d) and (e) of the 1922 Act is necessary.

48. We have not neglected to consider whether the safe siting of celluloid storerooms could be achieved by prescribing specific minimum "safety distances" to be observed between storerooms and other buildings. We have come to the conclusion, however, that it is impracticable to prescribe a rigid formula of minimum distances sufficient to guarantee complete safety in all cases. The only experimental data available to us derived from experiments not with celluloid but with analogous substances such as nitro-cellulose powders. The experimental data were based on materials which were stored unboxed and in storerooms which were not related to our standards. Although we have not felt able to adapt these data to the purpose of defining minimum safety distances from celluloid storerooms, we think the data of sufficient general interest to justify inclusion in Appendix II.

49. We accordingly recommend that Section 1 (1) (d) and (e) of the Celluloid and Cinematograph Film Act, 1922, should be amended in general terms (see paragraph 85, D and E).

50. We recommend that all storage of film and of scrap, shall be either in a single-storey building or on the roof or top floor of a building with adequate structural fire separation (see below) from the remainder of the building and from other adjoining buildings. This will require amendment of the 1928 and 1939 Regulations so far as factory premises are concerned and of the Schedule to the Act of 1922 in respect of other premises.

### *Amount of celluloid in storeroom*

51. We do not consider that our storage recommendations need be applied to premises in which less than 80 lbs. of film or scrap celluloid or 1 cwt. of celluloid in any other form is stored. Where scrap material which includes celluloid is stored, this exemption should only apply if the total amount of scrap material on the premises is less than 80 lbs.

52. As regards cinematograph and other film, comparable thin sheet celluloid, and also scrap or waste celluloid we consider that the maximum amount to be kept in any storeroom should be 1 ton. This will require amendment of the First Schedule to the Act of 1922 as well as of the Regulations of 1921, 1928 and 1939.

53. In association with the amount of material to be kept in one storeroom the size of each storeroom arises. We do not consider it necessary to prescribe a fixed area of floor space for each ton of a specific type of celluloid stored, though on general principles it is desirable that all storerooms should be kept as small as practicable. The application of this principle not only serves to eliminate the tendency to overstock the storeroom, which is a temptation where more than sufficient space is available, but facilitates means of escape, which are difficult to ensure in large storerooms.

54. We have considered how far there should be limitation of the amount of celluloid in relation to the number of storerooms either in one building or in one area. In our view, if storerooms are up to the standards recommended in this Report there should not be a need also to control the number of storerooms. In the interests of good and sensible administration we consider it essential that consultations should be maintained between H.M. Inspectors of Factories and the officers of local authorities as to the storerooms with which they are respectively dealing.

#### *Structure of Storerooms*

55. In Mr. Long's report, paragraphs 29 and 30, there is a vivid picture of the destruction of a two-storey building and of a single-storey building in which celluloid scrap was stored. Roofs, doors, partitions, walls, containers of scrap, were destroyed, but substantial parts of the outer walls remained standing after the fire. The evidence of other fires repeats this picture of ruin after fires involving scrap celluloid or film.

56. Our general conclusions are that (subject to the next paragraph) storerooms should be so constructed that they are able to confine a fire and to prevent communication to the contents of the storeroom of a fire occurring outside it, and to withstand the pressure of gases generated by decomposing celluloid. To achieve that object the structure should be of such a grade of fire resistance that it will withstand, without collapse, the effects of a fire during which the contents are completely consumed. Furthermore it should ensure that transmission of heat through the structure does not result in a dangerous rise of temperature on the surfaces remote from the fire and thus prejudice the contents of adjoining storerooms. There should be no openings in a storeroom other than those approved for the doorway, the gas relief space, and ventilation. Subject to any specific recommendations made in this report, the materials and construction of walls, floors and roofs should conform with current structural standards and codes of practice. (Relevant codes are mentioned in Appendix IV.)

57. The temperature rise criterion on which the standard of basic construction recommended in paragraph 58 is based is not applicable to raw celluloid, but, having regard to the contents of Appendix III, we are of opinion that, except in circumstances where the transmission of heat through the structure is not important, the basic construction of raw celluloid storerooms should be of not less than  $4\frac{1}{2}$  inches solid brickwork or 4 inches of concrete or other material of equivalent fire resistance and that "fire resisting materials" should be defined accordingly.

58. The standards we recommend for the *walls, ceilings and floors* of film and scrap celluloid storerooms are as follows:—

(1) The basic construction must be such as to withstand a pressure of not less than 1 lb. per square inch, and in any case be of not less than  $8\frac{1}{2}$  inches solid brickwork or 6 inches of reinforced concrete or other material of equivalent strength and fire resistance, subject to any more stringent requirements necessary for normal structural reasons.



(2) It is important that the structure should not permit penetration of hot gases generated during a fire.

(3) In circumstances where transmission of heat through the structure is not important, the structure forming the external walls and roof of the storeroom may be not less than 4 inches of reinforced concrete.

(4) Where a structural framework of steel or reinforced concrete forms part of the structure of the storage it should be of a standard of fire resistance not less than that of the structure it supports, and structural steelwork should be protected in accordance with the structural standards and codes of practice (see Appendix IV).

The practical considerations which affect the required standard of construction from the normal fire protection standpoint only are given in Appendix III. Additional precautions are necessary to prevent damage to the structure by explosion and consideration is given to these in paragraphs 67 to 70.

59. *Doors and door fastenings* present special difficulties, especially as a door will not necessarily be closed at the moment a fire breaks out. Doors should be self-closing, should open outwards (see paragraph 61) and be of adequate fire resistance. They should, together with their mountings and fastenings be of sufficient strength to withstand the pressure of the gases given off by the decomposing celluloid until the gas relief space (see paragraphs 67 to 70) operates. They should not readily transmit heat.

60. We are informed that it is doubtful whether there exists at the moment a specification for a door which would meet the above requirements as to fire resistance. Doors of solid oak or teak at least two inches in thickness, are defined as fire resisting doors under the Regulations of 1928 and 1939. This basic standard may be supplemented by metal sheathing to increase the general standard of fire resistance of the door.

61. Door openings should be no larger than is necessary, having regard to loading facilities, e.g., to enable trolleys to enter the storeroom. In no case should a doorway be so large that it unduly weakens the structure or reduces the fire resistance of the storeroom. Where a wide door is essential it may not be practicable to use a hinged, self-closing door which opens outwards. In such circumstances there may be a case for the use of a self-closing sliding door. Where, however, a sliding door is used, the door should slide on the outside of the storeroom wall and be so arranged that when closed it is properly secured at the bottom and sides so as to withstand the pressure of gases until the gas relief space operates. Special attention should be given to means of escape from the storeroom, e.g., by way of a hinged portion opening outwards in the sliding door, or otherwise. A fusible link should not be used in connection with a self-closing door.

62. The frames of the doors should be adequately secured to the main fabric of the structure and special regard should be had to the strength of hinges and locks and the method of fixing them. All hinged doors should open outwards in the direction of the exit, although in making this recommendation we are having regard not to the storage conditions but to the safety of any persons who may be in the storeroom. Hinged doors should close into ample rebates to restrict as far as possible the passage of flames and gases. Whatever the latching or locking arrangement, it should in all cases be possible to open the door easily from the inside without using a key or other removable implement.



63. It is necessary that any *corridor* into which the door of a storeroom opens should be of the same standard of construction as the storeroom itself in all respects. Where storerooms are sited on both sides of a corridor (which we deprecate) the doors opening into the corridor should be so arranged that no two doors are directly facing one another. Furthermore, any corridor into which storeroom doors open should be of sufficient width to provide adequate means of escape in case of fire (having regard to any possible obstruction, e.g., trolleys or other equipment necessary in the day-to-day operation of loading and unloading stores), and should possess not fewer than two exits suitably positioned.

#### *Containers, Racking, etc., in Storerooms*

64. Except in so far as the 1928 Regulations and the London Act of 1915 require that each reel of cinematograph film, whether in a storeroom or not, shall, if not exposed for purposes of work, be kept in a separate box, properly closed and constructed of metal or some other approved material, the existing codes of requirements do not deal with the containers in which celluloid or film shall be packed when in storerooms. It is therefore permissible to pack scrap film loosely into a storeroom, or to keep it in sacks, which may, under certain circumstances, promote ignition. We consider therefore that, in future, it should be laid down that all film or scrap or waste celluloid should be kept in storerooms and in properly closed containers of metal or other approved material.

65. Storeroom fittings (apart from electrical fittings) are mentioned only in the London Act of 1915 and the Act of 1922, which require them to be, so far as is practicable, of non-inflammable or fire resisting construction. We have found that racking is employed in storerooms of most kinds and we consider that this racking should in all cases be of such a type that it will not readily conduct fire. We do not consider, after hearing our witnesses, that it is necessary to prescribe the method of stacking the containers.

#### *Ventilation and Gas Relief*

66. *Ventilation.*—All the existing codes of requirements relating to the storage of celluloid and cinematograph film, with the exception of the Celluloid Regulations, 1921, require storerooms to be adequately ventilated.

The ventilating arrangements can best be associated with gas relief space. They must be subject to certain restrictions, having regard to the possibility that, in the event of decomposition of the celluloid in the storerooms, toxic and explosive gases will be released and, if fire occurs, flames will be transmitted through ventilation openings as well as through the gas relief space, if there is separate provision. The most direct outlet to the open air should be provided, and care should be taken that any flame issuing does not endanger other buildings. Where ventilation is by means of trunking the latter should be of the same strength as the main fabric, and, if necessary, be plastered to prevent the penetration of gases through the fabric.

#### *Gas Relief Space*

67. When celluloid is decomposed by means of heat a large volume of gas is evolved (see Appendix V). The quantity and nature of the gases evolved depend upon the conditions under which decomposition occurs. The gases are poisonous and when mixed with air they are liable to form an explosive mixture. We understand that one pound of celluloid when decomposed by means of heat will yield approximately eight cubic feet of gas, which will form an explosive mixture with any quantity of air within the limits of 12

to 72 cubic feet and that when the mixture of the gas and air is fired, the pressure produced may be of the order of 120 lbs. per square inch. It is impracticable to construct a storeroom to withstand such a pressure, and it is therefore an essential that every storeroom should be provided with gas relief space sufficient to prevent the pressure built up within the storeroom exceeding that which the building can withstand, namely, 1 lb. per square inch.

68. The late Professor Wheeler carried out experiments at Buxton in order to determine the amount of gas relief space required to prevent the pressure generated rising above 1 lb. per square inch, and, as a result of his investigations, he found that the minimum space required was  $6\frac{1}{2}$  square inches for every cubic foot of storage space.

69. Having had regard to the provisions regarding gas relief space contained in the Regulations of 1928 and 1939, and in paragraph 175 of the American Standards,\* all of which differ, and to the findings of Professor Wheeler, we have come to the conclusion that the last mentioned standard (which is authoritative, based on experimental data, and specifies the greatest area for the relief of pressure) should be adopted for all film and scrap storerooms. Gas relief space to this standard would work out at 1,456 square inches in a store measuring 4 feet by 7 feet by 8 feet high or in other words, approximately 33 inches by 44 inches. This ratio of  $6\frac{1}{2}$  square inches for every cubic foot of storage space is, it must be stressed, a minimum figure, and where provision is made for the gases evolved during decomposition to be conveyed to the open air by means of trunking, which we deprecate, the area of the gas relief space and the cross-section of the trunkings must be increased so as not to impede the flow of the gases in the trunking.

We do not regard the provision of gas relief space as essential in storerooms for raw celluloid, provided that the roofs of such storerooms are of extremely light construction.

70. Gas relief space should not be so arranged as to weaken the storeroom structure. Moreover, unless the gas relief space is permanently open to the outside air it is essential that the protective covering should give way on rise of pressure before any structural element of the storeroom fails. The character and bursting resistance of the protective covering, its means of fixing and the area of individual elements making up the aggregate area of the gas relief space should be very carefully controlled. Any cover to the gas relief opening which may be necessary, e.g., for protection against the weather or the entry of burning material, should therefore be such that only negligible resistance is offered to the egress of gases, e.g., a single sheet of 1/12 inch sheet glass, lightly fixed in position, or merely laid on if the opening lies in a horizontal plane. If any hinged frame is employed careful maintenance is essential to ensure that the hinges at all times operate with complete freedom. The gas relief space must be carefully positioned. It should preferably be in the roof, but in any event should be protected against the direct entry of the sun's rays, e.g., by shading, etc. The outlet should be so placed that any burst of flame from it would not involve any other storeroom or other building within the flame radius. Where necessary baffle walls, of the same standard of fire resisting construction as the fabric of the store, should be erected to direct flame away from any such other building. Finally, it is very desirable that some form of guard, e.g., expanded metal, offering negligible resistance to the passage of gases,

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\* The Standards of the National Board of Fire Underwriters for Nitro-Cellulose Motion Picture Film. N.B.F.U. Pamphlet No. 40, 1949.



should be fitted across the actual outlet provided by the gas relief space, in such a manner as to prevent the ejection of burning material (and to afford any necessary protection to any covering provided), but so as not to interfere with the operation of the gas relief space.

### *Heating*

71. To safeguard against deterioration of cinematograph film it may be necessary to maintain the storeroom at an equable temperature. Trade witnesses gave 50° to 60° Fahrenheit as a desirable temperature. It may not always be possible to make use of heating from outside the storeroom (heating inside the storeroom is forbidden by Regulation 5 of Part III of the First Schedule to the Act of 1922, but not by the Factory Regulations) and in such circumstances we are satisfied that storerooms may be heated from within, provided, however, that the heat is effectively regulated and that the actual heating element is so guarded or enclosed as to prevent ignition or decomposition of cinematograph film. In this connection we would draw attention to the requirements of Regulation 14 (vii) of the 1939 Regulations, which we consider to be satisfactory. This Regulation reads of follows:—

“ Resistances, including the heating elements of electric heaters and radiators, shall be so guarded or enclosed as to prevent ignition or decomposition of cinematograph film. The top of the enclosure or guard shall be sloped at an angle of not less than 45°.”

### *Lighting*

72. We consider that the lighting fittings in all storerooms should be of the protected type in which the lamp is totally enclosed. We understand that this type of fitting is already in general use. As far as electrical requirements generally are concerned we are of opinion that the provisions of Regulation 12 of the 1928 Regulations and Regulation 14 of the 1939 Regulations are adequate and should apply to all storerooms, and to manipulation rooms, subject to the exclusion from storerooms of all electrical apparatus other than that which is essential to be in the room for the purpose of lighting or heating it. The switches and any other non-essential equipment should be outside the storeroom.

### *Means of Escape*

73. There are various provisions which directly or indirectly provide for control over the means of escape, e.g., the certifying of means of escape by the local authority under the Factories Acts ; the provisions in the Act of 1922 Section 1 (1) (b) and (d) ; the powers under Section 60 of the Public Health Act, 1936. We are proposing (see paragraph 85D) that Section 1 (1) (d) of the Act of 1922 should be amended to secure that means of escape from property in the vicinity of celluloid storerooms should not be endangered. If our proposal is accepted it will be necessary to make sure that its implementation is not inconsistent with other statutory provisions on means of escape, and in particular that the measures available for London, under the local Act of 1915, are fully maintained, having regard to the special risk in London.

### *Means of Extinguishing Fire*

74. A major point to be considered is the provision of adequate means of extinguishing fire. We are of the opinion that the most effective apparatus which can be employed to control a celluloid fire or to prevent the ignition



of celluloid when the temperature of the storage accommodation is rising dangerously is an automatic water sprinkler system, arranged also for hand operation. Most trade representatives thought sprinklers were effective, but some thought that fire in loose film, when stored in bulk, spreads far too rapidly for it to be extinguished by any normal sprinkler system. The proposal to keep this material in fire resisting containers (paragraph 64) will reduce the risk of film, even unreeled film, being consumed immediately. We feel, therefore, that a sprinkler system is advisable in all cases to prevent spread of fire. We have had regard to other methods of controlling fires involving celluloid, and understand that the use of an inert gas such as  $\text{CO}_2$  in conjunction with a water spray system is another method of fire extinguishment, but we have had no evidence on which we can at the moment advocate a system of this kind for general use. We recommend that the provision of an efficient automatic water sprinkling system should be made obligatory in all storerooms used for the storage of celluloid and cinematograph film excepting where, in the opinion of the appropriate authority, the provision is unnecessary for the protection of persons employed or of surrounding property, and further that the operation of the sprinkler system should simultaneously operate a warning distinctly audible both inside and outside the premises. Failure in this respect was in part responsible for the deaths arising out of the Richmond fire. There should be weekly testing of the system to ensure proper functioning.

75. As far as cinematograph film storerooms are concerned, we have considered the sprinkler provision advocated by Mather and Platt Ltd.; as a result of tests which they carried out in 1932.\* It must, however, be realised that the provision of sprinklers advocated by them is on a very extensive scale, with the object of saving the contents of the storeroom and confining fire and decomposition of film to the single tin in which it began. We do not feel justified in suggesting that such a provision is essential to prevent the spread of fire from a storeroom. We recommend a provision of sprinklers adequate to arrest and suppress flame and to cool the contents of the storeroom. Thus we recommend the provision of three sprinkler heads in each normal storeroom for one ton of film (viz., 7 feet by 4 feet by 8 feet high), two sited so that they will play directly over the tins of film and over the adjoining walls, and the third arranged as a drencher over the door. Where abnormal risks exist in a particular neighbourhood it may be necessary to provide sprinkler heads in excess of the above recommendations.

76. For celluloid storerooms other than those to which paragraph 75 applies, we consider that the sprinkler provision should be not less than one head for every 64 square feet of floor area or part thereof, the heads being not more than 8 feet apart and sufficient in number to ensure that no portion of a wall in the same horizontal plane as the sprinkler heads is more than 6 feet from a head, the heads being arranged to ensure that water will spray over all the celluloid stored in the room.

77. We have also had regard to the allied necessity of adequate water supplies, and are of opinion that each sprinkler installation should be connected to a primary and, wherever practicable, to a secondary source of water supply, excepting where, in the opinion of the appropriate authority, this provision is unnecessary for the protection of persons employed or of surrounding property.

---

\* "Suggested Fire Protection of Motion Picture Film Stored in Vaults" Mather and Platt Ltd., Park Works, Manchester.

### *Miscellaneous provisions*

78. It is desirable that all storerooms should carry prominently posted warning notices externally displayed, and bearing the following information :—

(a) the amount and kind of the material (viz. raw celluloid, manufactured articles, cinematograph, etc., film or scrap celluloid) allowed to be kept in the storeroom, and that the storeroom is exclusively restricted thereto ;

(b) that there is a prohibition of smoking and of any activity which would lead to fire in or in the vicinity of the storeroom.

79. A point on which we would wish to lay great stress is that care, maintenance, staff training, supervision and enforcement, which may be called "good housekeeping" is of the utmost importance in the safekeeping of materials such as celluloid, with their high risk. The fact that initial compliance with a rigorous standard of safety conditions is secured is not enough. Unless continuous attention is given to standards of this kind, there will be a progressive reduction in the degree of security originally provided, arising from such things as defective sprinklers, warped doors, obstructed or ineffective gas relief spaces and, not least, from personal carelessness. It is therefore incumbent upon the owners of storerooms to ensure that regular inspections of storage accommodation and tests of equipment are made and that strict attention is given to the observance of safety rules for the purposes of avoiding the dangers attendant upon disrepair or slackness.

### *Manipulation Rooms*

80. As was mentioned earlier in this Report we have felt it relevant to pay some regard to activities carried on in rooms so situated that fires in these rooms might spread to storage accommodation. These rooms are those in which cinematograph film or scrap or waste celluloid is handled, e.g., workrooms, projection rooms, and examining, sorting, packing and despatch rooms. We class them together as manipulation rooms.

81. All the existing codes contain certain provisions to regulate safety standards in these rooms, as by restricting the amount of exposed material to the smallest practicable limits, avoiding the accumulation of waste, and requiring measures to prevent fire and to provide adequate means of escape, and the later codes impose improved standards which should be made uniform. Certain provisions seem to us to require to be strengthened even in the most up-to-date codes.

82. We agree with the principle underlying the existing requirements that at no time should there be, in rooms of this description, a greater quantity of celluloid or film than is absolutely essential for the operation which is being carried on, and we think that it would be desirable if this maximum quantity were to be definitely specified in respect of individual premises by the administering authority. There are existing standards of construction for such rooms which we consider should not be lowered ; the rooms should be fitted with sprinklers (a requirement not at present imposed), and arrangements for lighting and heating should be of a type not likely to ignite or decompose celluloid or film. Fittings should be of fire resisting material, and there must clearly be a retention of the present restriction upon the introduction of smoking materials and other inflammable materials into these rooms. With regard to rooms which are used for the examination and repair of cinematograph film we were concerned to find that there is no limitation on the amount of inflammable solvent kept by the workers for repair



operations. We recommend that each operator engaged on repair work should be supplied with not more than one 2 oz. bottle of solvent at a time, and that stocks of solvents should be kept outside such rooms. The trade witnesses who were consulted on this point have confirmed that such a requirement would be practicable.

83. One further point which we consider is essential to make is that the need for good housekeeping, to which reference was made in paragraph 79, is particularly important in rooms where celluloid of any description is exposed and subject to continuous handling.

## CONCLUSIONS AND SUMMARY OF RECOMMENDATIONS

84. Our enquiries have confirmed that celluloid in all its forms is highly inflammable and that the greatest dangers are presented by scrap celluloid, cinematograph and other film and by celluloid in the form of strips or sheets which approximate in thickness to cinematograph film. This high inflammability is the reason for the existing statutory controls over the storage of celluloid, but the continued occurrence of serious fires in the more readily ignitable types of celluloid, often accompanied by explosion, has convinced us that in certain respects higher standards of precaution are necessary.

Reliable evidence as to the actual causes of the fires which have occurred is almost entirely lacking and in considering the nature of the further precautions we have, therefore, necessarily directed attention to the means of preventing the spread of fire and the occurrence of explosion once fire has broken out. Further, as we have pointed out, the existing controls are applied through the medium of no less than two general and three local Acts of Parliament and three sets of regulations, enacted or made at various dates between 1915 and 1939 and this circumstance has given rise to a number of anomalies.

Our conclusions may be summarised as follows:—

(i) All celluloid storage should be subject to common standards, whether storage is in factory or non-factory premises. The requirements contained in the various codes of factory regulations and in the Schedule to the Celluloid and Cinematograph Film Act should accordingly be amended to conform to these common standards, and the standards in the local Acts should be superseded by standards of general application.

(ii) All celluloid and cinematograph film, in excess of the prescribed minimum quantities, should be controlled with the exception of manufactured celluloid goods in shops (paragraphs 6, 46 and 51). This will entail further control of photographic film (paragraph 21). The standards should, however, vary in relation to the type of celluloid stored (paragraph 19), and for storage purposes we have divided celluloid into four categories: raw celluloid, manufactured celluloid goods, cinematograph and photographic (including X-ray) film, and scrap or waste celluloid (paragraphs 6 and 46). The administrative authority should have some discretion to relax requirements in exceptional circumstances (paragraphs 9 and 46). Consideration should be given to a change in the local authorities empowered to administer the Act of 1922 (paragraph 26). Consultation between H.M. Inspectors of Factories and local authority inspectors should be maintained (paragraph 54).

(iii) All storerooms should be so sited as not to endanger persons and property in the vicinity (paragraph 49), and those for film and scrap should be in single-storey buildings or in a top-storey position (paragraph 50). Adequate means of escape are essential (paragraph 73). All store-



rooms should be of adequate fire-resisting construction (paragraphs 57-62), as should adjoining corridors (paragraph 63), and, unless the administering authority decides otherwise be fitted with sprinklers (paragraph 74). They should be as small as practicable (paragraph 53), have non-inflammable fittings (paragraph 65), and bear warning notices (paragraph 78). Heating and lighting must be controlled (paragraphs 71 and 72).

(iv) Not more than 1 ton of film or celluloid scrap should be kept in one storeroom (paragraphs 46 and 52), but it is not necessary to restrict raw celluloid and manufactured celluloid goods to this extent (paragraph 46). There should be provision of adequate gas relief space and ventilation in all film and scrap storerooms (paragraphs 66 to 70). All film scrap in storerooms must be kept in proper containers (paragraph 64).

(v) Manipulation rooms must be of adequate fire-resisting construction and protected against the risk of fire (paragraph 82).

(vi) Good housekeeping is important (paragraphs 79 and 83).

(vii) We intend that there shall be no relaxation of existing statutory provisions which are not specifically dealt with in our Report (paragraph 45).

85. We consider that the following major changes in the existing legislation will be necessary to give effect to our recommendations.

A. Amendment of Regulations in the First Schedule to 1922 Act and of Regulations made under the Factories Acts in accordance with recommendations in paragraphs 55 to 79 as respects basic construction, doors, corridors, gas relief spaces and outlets, ventilation, heating and lighting for film and scrap storerooms, sprinklers, smoking warning notices, quantities stored, and manipulation rooms, inspections, and tests.

B. Retention of H.M. Chief Inspector of Factories' power to exempt from all or any of the provisions of the regulations if he is satisfied that in any particular circumstances they are not necessary for the protection of the persons employed, or, in the case of existing premises are not reasonably practicable, the Chief Inspector also having power to attach conditions to a certificate of exemption and to revoke it at his discretion.

C. Amendment of Section 1 (1) (f) of 1922 Act to confer similar powers of exemption on local authorities, as respects non-factory premises.

D. Amendment of Section 1 (1) (d) of 1922 Act so that it applies in the case of any building (e.g. substitute "other" for "adjoining").

E. Amendment of Section 1 (1) (e) of 1922 Act as follows:—

S. 1 (1). No premises shall be used for any purpose to which this Act applies—

.....

(e) Unless the premises are so situated and constructed that a fire occurring therein is not likely to spread to other parts of any building of which the premises form part or to endanger persons or property in the vicinity.

F. Revocation of Section 11 (2) of the 1922 Act and amendment of Section 11 (3) of that Act so as to apply it to London and Glasgow as well as to Liverpool, subject to the retention, for London, of any powers in the Act of 1915 which are additional to those in the Act of 1922.

G. Amendment of the definitions in Section 9 of the 1922 Act which relate to "raw celluloid", "cinematograph film" and possibly "local authority", and amendment of the Regulations made under the Factories Acts with regard to the classes of materials to which such Regulations should apply.

### *Introduction of New Standards*

86. There are various considerations either of general application or particular to our problem which have a bearing on the introduction of our recommendations at present time. There is the fact that the standards of structure advocated in this report are not to be found in the majority of existing storerooms, and that some storerooms may not be suitable for adaptation, e.g., where space is limited or existing walls are of unsuitable material, conversion to our suggested standards may present considerable difficulties. Furthermore, our requirements as to siting may preclude the further use of some premises which are at present used as storerooms. Apart, therefore, from some repercussions upon supplies of material and the available labour force, the implementation of our recommendations, by reason of its effect upon existing accommodation, may well result in some dislocation within the celluloid and cinematograph film industries.

A further point arises from the likelihood that nitro-cellulose film may eventually be superseded by films on a cellulose tri-acetate or other slow-burning base, but it cannot yet be foretold how soon or to what extent this may occur. It may be, however, that some of the premises which are now used for the storage of nitro-cellulose film will, in a few years' time, be storing slow-burning film only.

87. In the circumstances we feel that although, in the interests of safety, no less effective standards than those we have recommended are acceptable for new buildings, it may, in the light of current difficulties, be impracticable to give immediate effect to them in existing buildings, and we suggest that any new requirements shall apply as soon as it is reasonably practicable to carry out the necessary additions or alterations, and in any event shall become fully effective at the expiration of a period of three years from the coming into operation of such requirements.

88. We wish to record our thanks to our Secretary, Mr. Rudd. In the conduct of our enquiry and in the preparation of our report he has given us the greatest and most cordial assistance.

J. I. WALL (*Chairman*).  
H. ECCLES.  
J. C. FARNSWORTH.  
W. GAYTON.  
H. R. HODGES.  
B. J. JESSUP.  
H. E. SKILLERN.  
S. D. STUDD.  
H. E. WATTS.

G. T. RUDD (*Secretary*).  
Home Office,

30th January, 1950.

## APPENDIX I

### A. List of witnesses consulted by the Committee

Mr. Merriam ...	...	...	...	}	The British Plastics Federation
Mr. Foster Sproxton ...	...	...	...		
Dr. Diamond ...	...	...	...		
Mr. Walton ...	...	...	...	}	The British Film Producers' Association
Mr. Tripe ...	...	...	...		
Mr. Drake ...	...	...	...		
Mr. Phillips ...	...	...	...	}	Kinematograph Renters' Society
Mr. Wackett ...	...	...	...		
Mr. Percival ...	...	...	...	}	The Plastics Institute
Dr. Yarsley ...	...	...	...		
Captain Moon ...	...	...	...	}	Film Strippers' Association Ltd.
Mr. Collins ...	...	...	...		
Mr. Foster Sproxton ...	...	...	...	}	British Employers' Confederation
Mr. Alford ...	...	...	...		
Mr. Staley ...	...	...	...		
Mr. Brogan ...	...	...	...		
Mr. Moll ...	...	...	...		
Mr. Mewett ...	...	...	...		
Mr. Baxter ...	...	...	...		
Mr. Lambeth ...	...	...	...		
Mr. Honey ...	...	...	...		
Mr. Miller ...	...	...	...		
Mr. Cole ...	...	...	...		R. H. Cole and Co. Ltd.

### B. Premises visited by the Committee

- A celluloid manufacturer.
- A film manufacturer.
- A film processing laboratory.
- A film cutting establishment.
- Two film distributing firms.
- A film stripping factory and rented film storerooms.
- A hospital (storage of X-ray films).

### C. Areas in which enquiries were made

The Committee instituted investigations and received reports from His Majesty's Inspectors of Factories and local authority officers on celluloid storage in the following areas: Manchester, Sheffield (since celluloid is used in the cutlery trade), Leicester (as celluloid is also used in the boot and shoe industry), Birmingham, Cardiff, Bristol, Elstree, and in Islington and Westminster in the London County Council Area.



## APPENDIX II

**Table of safety distances (see paragraph 48)**

The data given below are based on experiments with Category Y explosives (which have substantially similar fire risks to celluloid), carried out by the Explosive Storage and Transport Committee (a committee constituted by the Minister of Supply to consider, inter alia, the siting, construction and maintenance of storerooms for explosives).

**ALL DISTANCES ARE IN FEET**

Nett Quantity Lbs.	Safety Distance	Nett Quantity Lbs.	Safety Distance
100	30	50,000	129
200	30	60,000	139
400	30	80,000	159
600	30	100,000	174
800	35	150,000	208
1,000	40	200,000	236
2,000	46	250,000	260
3,000	50	300,000	283
4,000	54	350,000	304
5,000	57	400,000	322
6,000	60	450,000	339
8,000	64	500,000	354
10,000	69	550,000	366
15,000	79	600,000	382
20,000	88	800,000	435
30,000	103	1,000,000	480
40,000	118		

## APPENDIX III

### **STRUCTURE: MAIN FABRIC FIRE RESISTANCE STANDARDS**

The following statement deals with the standards of construction of celluloid storage chambers from a fire protective standpoint only. The conclusions are based essentially on an assumed basis of exposure of one hour. They do not take into account the effects of explosion and any additional requirements in that connection should be superimposed on them. The siting of the chamber is considered only in so far as it affects fire resistance standards. Doors have not been discussed.

A standard of construction to comply with the requirements set out in paragraph 56 is described in Part I of the Report of the Fire Grading of Buildings Committee as "fully protected construction" and the grades of fire resistance are determined by reference to the fire load of the compartment. The relation is, however, based essentially on the characteristics of fires in materials such as paper, timber and fabrics, and it is indicated that further consideration is necessary to assess requirements for fires of appreciably different characteristics.

Fires in celluloid are a case in point. The temperature attained in a celluloid fire is usually higher than that in other materials and higher than the maximum attained in the British Standard fire resistance test by means of which the grades of fire resistance are determined. On the other hand, for equal fire loads the duration of a celluloid fire would, owing to the high rate of burning, be considerably less than that of a fire in more normal materials. It is therefore necessary to consider what effect these different conditions will have on the structure.

Furthermore, in respect of transmission of heat through the structure, grades of fire resistance as determined by the British Standard test\* are based on a temperature rise criterion of 139° C. (250° F.). On account of the low ignition temperature of celluloid and the risk of exothermic decomposition, that temperature rise could not be tolerated on the surface of a wall or floor adjacent to the celluloid<sup>†</sup> stored.

It is therefore necessary to determine fire resistance requirements for celluloid storage on a much modified basis. In the absence of satisfactory experimental data it has been necessary to rely largely on experience in dealing with both factors, though in the case of the latter some guidance has been forthcoming from existing test data and rough calculations.

*Effect of Celluloid Fires on Structures.* Experience of celluloid fires indicates that their effects on the structure are not more severe than fires in heavily loaded warehouses containing other materials. There are several possible reasons for this. First, as already noted, the duration of celluloid fires is relatively short and this may be sufficient to counterbalance the higher temperature. The very high temperature often melts the surface of brickwork but this effect is confined to a small depth from the exposed surface. A second factor is that the combustion of the products of decomposition may not be complete within the chamber owing to deficiency of oxygen and consequently the effective fire load is much less than the fire load circulated on the full calorific value. Thus, while the calorific value of celluloid burnt in ample supply of air is of the order of 8,000 B.Th.U./lb., it may fall, for example, to about  $\frac{1}{3}$  of this value or even lower when combustion occurs in restricted air supply. Whilst it is not possible to estimate quantitatively what may occur in a store, there is evidence to show that much of the combustion occurs outside where the gases become mixed with excess air. This means that the standard store containing 1 ton of celluloid spread over 28 square feet would have a gross fire load of about 600,000 B.Th.U./square feet which would be reduced to about 80,000 B.Th.U./square feet on the basis of the low value quoted above.

For the maximum fire load a fire resistance of at least 6 hours would be needed if the relation between fire load and fire resistance given in the Fire Grading Report held good, but on account of the shorter duration the relation cannot be accepted, despite the fact that higher temperatures persist which will counter in part the effect of the shorter duration. Moreover, it is implicit in the relation that the temperature rise criterion is 139° C., but as celluloid starts to decompose at much lower temperatures, it is necessary to adopt a lower figure.

*Temperature Rise Criterion.* We have reached the conclusion that in order to restrict spread of fire due to heat transmission through the structure separating two storerooms, a fire in one storeroom should not cause a temperature rise of more than 70° C. on the unexposed surface<sup>†</sup> of the separating structure. In considering what thickness of various types of wall would be needed to ensure that this value is not exceeded, it is useful to note the temperature rises on the unexposed surface of walls when the other surface is heated in accordance with the standard time-temperature curve of B.S. 476. On the assumption that the initial temperature is 15° C., the temperature rises on unexposed surfaces of various walls after  $\frac{1}{2}$  hour, 1 hour and 2 hours heating are given in Table I.

If the maximum temperature of a celluloid fire rises to, say, 1,400° C., the corresponding temperature rises on the unexposed surface may be assumed to be 50 per cent.<sup>‡</sup> greater than the values in Table I. It is evident then, that after 1 hour's exposure only 8½ in. of brickwork or 6 in. of concrete would limit the temperature rise to less than 70° C., whilst after 2 hours' exposure neither 8½ in. of brickwork nor 8 in. of concrete would be adequate for this purpose. The temperature rise factor is clearly the major consideration and a satisfactory solution depends entirely on the duration of exposure that is likely to occur. There are no experimental data to which we can refer but experience suggests that it is unlikely that the maximum

\* British Standard Definitions (No. 476, 1932) for Fire Resistance, etc. of Building Materials and Structures.

† The unexposed surface is the surface opposite to the surface exposed to the fire.

‡ This is, of course, an approximation as it is based on the fire temperature and not the exposed surface temperature.

temperature in a celluloid fire will persist for more than 1 hour and that it may be even less than  $\frac{1}{2}$  hour. If the requirements are based on a duration of 1 hour,  $8\frac{1}{2}$  in. brickwork or 6 in. concrete structures or their equivalent will be needed. It may be noted that the American National Board of Fire Underwriters requirements for film vaults accord with the conclusion based on 1 hour exposure, but it may be that other factors have influenced this decision. The above discussion relates primarily to those circumstances in which fire in one of a group of storerooms endangers celluloid in an adjoining storeroom.

TABLE I

*Temperature Rises on Unexposed Surfaces after B.S. Heating*

Material and Thickness of Wall				Temperature Rise above 15° C. on Unexposed Surface in ° C. after		
				$\frac{1}{2}$ hour (Max. Temp.* 843° C.)	1 hour (Max. Temp.* 927° C.)	2 hours (Max. Temp.* 1010° C.)
Brickwork (Clay)	$8\frac{1}{2}$ in. ....			5	15	85
	$4\frac{1}{2}$ in. ....			35	85	185
Concrete 1 : 2 : 4	8 in. ....			10	35	75
	6 in. ....			15	42	85
	4 in. ....			35	75	125
Clinker Concrete Blocks	3 in. block with $\frac{1}{2}$ in. plaster each side.			65	75	85

\* On exposed surface.

It is necessary also to consider the fire resistance requirements of walls and floor separating the celluloid storage from other parts of a building. Two sets of conditions have to be considered; first, the requirements for minimising the risk of fire spreading from the building into the store and, second, the risk of spread in the opposite direction. The need for adopting the lower temperature rise criterion in the former case will be apparent and this will therefore be the determining factor. The required grade should be related to the expected fire severity in the building, i.e. whether office, factory, etc. in accordance with the principles laid down in Part I of the Fire Grading Report: but these standards again have to be modified to take account of the reduced temperature rise. It seems, again, that nothing less than the  $8\frac{1}{2}$  in. brickwork or 6 in. of concrete would be adequate, though for light fire exposure equivalent to 1 hour exposure in the standard test the thinner walls referred to in Table I might be taken as satisfactory. On the other hand for exposures equivalent to 4 hours, i.e. in warehouses where the fire load might be as high as 400,000 B.Th.U./square foot, still higher protection than  $8\frac{1}{2}$  in. brickwork may be needed.

In general, however, and to simplify the position as far as possible we would suggest that, solely from the fire protection standpoint, the  $8\frac{1}{2}$  in. brickwork or not less than 6 in. of reinforced concrete or their equivalent should be adopted as the standard enclosure for celluloid storerooms.

As this approaches construction which attains 4-hour fire resistance the requirements might be expressed in terms of that Grade but until further data are available on the effect of the lower temperature rise criterion it would seem desirable to limit the types of construction to those which are comparable in character, e.g. to concrete blocks or other solid construction. It is important that the structure should not permit penetration of hot gases generated during a fire. When doubt arises the walls should be plastered.



*Size of Store.* For fires in normal materials the grade of fire resistance of the structural elements of a building (required for fully protected construction) can be assumed to be independent of the size of the building. There are no data on this point in relation to celluloid fires, and it has been assumed that the conditions apply to the small film store and accordingly it is not possible to say whether higher grades are desirable in stores considerably larger than the standard storerooms. Unless evidence becomes available which suggests the need for higher standards it is proposed that the standard construction should be adequate from the fire resistance aspect for all sizes of storerooms.

Since the thickness of the enclosing structure has in this Appendix been determined primarily by the temperature rise criterion it follows that in circumstances where this is not a factor the thickness might be reduced. Accordingly, roofs or external walls of storerooms situated in the top storey of a building or erected on the roof of a building or as isolated structures on the ground may be of 4 in. reinforced concrete or other solid construction of equivalent fire resistance.

## APPENDIX IV

The following are the Chief Codes of Practice issued by the British Standards Institution relating to materials and construction which may be used in the construction of celluloid storage buildings:—

- |               |      |   |
|---------------|------|---|
| C.P. 111.101: | 1948 | Masonry including brickwork unreinforced.   |
| „ 111.102:    | 1948 | „ „ „ reinforced.   |
| „ 111.201:    | 1948 | Cast in situ concrete.  |
| C.P. 113:     | 1948 | Structural use of Steel in Buildings.   |
| „ 114:        | 1948 | Structural use of normal reinforced concrete in buildings<br>(Sub Codes 114.100-105). |
| C.P. 121.101: |      | Brickwork (in draft form only).   |
| „ 211.203:    |      | Internal Cement Plastering (in draft form only).                                      |

## APPENDIX V

### *Evolution of Gases on the Decomposition of Celluloid*

When decomposition of celluloid takes place in a limited supply of air, the gases evolved and their approximate percentages are of the following order:—carbon monoxide (30-40 per cent.), oxides of nitrogen (30-40 per cent.), hydrocyanic acid (0.2 per cent.), methane (2-5 per cent.), hydrogen (0.2 per cent.), carbon dioxide (12-17 per cent.) and nitrogen (4-10 per cent.).

In an excess of air they are:—carbon monoxide (4-6 per cent.), oxide of nitrogen (0.1-0.6 per cent.), carbon dioxide (7 per cent.), nitrogen (77 per cent.) and oxygen (9 per cent.).

The gases carbon monoxide, oxides of nitrogen, hydrocyanic acid, are poisonous.

The concentration of 0.01 per cent. carbon monoxide in air can be tolerated for continued exposure over long periods and 0.025 per cent. for short periods. According to one authority 0.04 per cent. is tolerable for periods of not more than one hour. In the case of hydrocyanic acid a concentration of 1 part in 50,000 parts produces slight symptoms of poisoning after several hours and 1 part in 10,000 becomes very dangerous within one hour.

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